1. Convert the snow bin into a snow tower, 10 or 20 feet high as required, by boarding down on the frame to the ground. Insert a galvanized iron, or a copper, tank of of rather large sectional area, say 3 feet square; slope the bottom boards of the floor of the bin so that the snow or rain will readily slip down into the tank; fill the space between the tower and the tank with hay, leaves, sawdust, or earth for a protection against cold winds and moderate freezes; put in a piece of rubber tube about 3 inches in diameter, to relieve the pressure on the the tank if the ice forms, so as to stand vertically in the tank from the bottom to the top; a good supply of light oil should be placed in the tank to check the evaporation; it is probable that a supply of salt will be useful in turning the snow into water, if the rusting effects on the metal of the tank can be avoided; the arrangement of door, ladder, and conveniences can be left to experience.

2. It would be well to take up the problems regarding the further development of the snow towers, in connection with the forest experiment stations, where the presence of suitable observers in the field will insure proper suggestion and supervision. It is my belief that by a proper adjustment of the *outside* louvers, some further improvement can be made in separating the horizontal drift from the vertical component of the fall.

3. There will be considerable expense connected with the construction and the installation of snow towers in remote mountain places, but it is evident that the problems of irrigation and water power will soon justify very considerable expenditures of money in this direction.

The following remarks on the seasonal snow gage are extracted from the reports from the section directors:

Denver, Colo., F. H. Brandenburg, Section Director.—I inclose a sketch[1] of a form of seasonal snow gage that I think will give satisfactory results with the use of salt and oil. The outside is the snow bin in use, with the exception that the boards extend to the ground with a low door. The floor is omitted. In the center is placed a metal cylinder about 24 inches in diameter and 6½ feet tall, the bottom resting near the ground. A faucet at the bottom similar to that on the tipping bucket gage will permit emptying the gage. About 4 feet above the bottom a tight-fitting door should be provided to permit inspection of the inside of the receptacle. This form of gage obviates the necessity of making an excavation to prevent freezing, as the snow that falls alongside the gage would afford as satisfactory protection from the cold as an excavation unless this were made very deep.

Portland, Oreg., E. A. Beals, District Forecaster.—After a careful study of the letters received from the snowfall observers in this State, I have concluded that the louvered bin, with sloping or hopper bottom opening into a metal or cement storage reservoir, is the only practical plan so far suggested; the use of salt and oil in the reservoir would avoid freezing and evaporation. The construction of the storage reservoir could be varied to suit the location of the bin. On some of the small benches in the mountains, the container could be sunk in the ground, but on the rocky slopes and summits this would be impossible unless blasting were resorted to. The construction and maintenance of these bins would undoubtedly be expensive. Among other plans suggested is that of a louvered bin with a depth of 10 feet or more; the bottom to be lined or made water tight to a height of 5 feet, and the winter snowfall to be allowed to accumulate in this bottom. Freezing and evaporation could be avoided by the use of salt and oil.

San Francisco, Cal., Prof. A. G. McAdie.—My opinions regarding the proper method of measuring snow are as follows:

1. Depth of snow is of less importance than the density of the snow.

[1] Omitted.

64——10

2. As far as possible we should record the water equivalent. At low levels this is best done by a weighing snow gage, something similar to Fergusson's automatic snow gage.

3. At elevations above 5,000 feet, and at inaccessible places, some gage of tank form will be necessary.

4. Prof. J. E. Church, jr., of the University of Nevada, Reno, has a form of gage which may be serviceable in sampling snow density during one or more day's travel.

5. Regarding the type of seasonal snow gage designed by the writer, I have received under date of March 27, a letter from Professor Church, in which the following occurs:

> The water in your tank at the ranch did not freeze a single time during the winter. If we can increase the diameter of the intake pipe to 18 inches without permitting undue evaporation from the tank, we can probably catch sufficient of the entire evaporation to indicate the essential fall of the snow. The narrow intake pipe is too small for winds, though satisfactory where calms exist.

I think Professor Church's suggestion a good one, either to increase the diameter of the intake pipe, or to combine some form of bin, properly louvered, with the tank arrangement below. There is, therefore, a general opinion that the louvered snow bin can advantageously be converted into snow towers for conserving a season's snow.

Judging from all these reports it would seem to be good policy to take the two following steps:

1. Introduce the snow bin at all Weather Bureau stations in the United States for the catchment of snow and rain.

2. Continue experiments with the snow bin towers in order to arrive at the best form of the apparatus for conserving a seasonal snowfall in places where no observers reside, but which can be visited twice each year, first in the autumn when snows begin to fall, and second in the spring just before melting takes place.

Without taking up further the developments of the snowfall in connection with the topography of a region, there are certain ideas which make it probable that the relations between snowfall and accumulations in the gulches and ravines can be worked out, if the necessary observations with snow towers can be secured.

THE TEMPERATURE CONDITIONS OF BOSTON, MASS.[1]

By ANDREW H. PALMER, A.M. Dated Cambridge, Mass., Apr. 28, 1910.

INTRODUCTION.

The following is an abstract of a quantitative study of the temperature conditions of Boston, Mass., based upon observations made by means of standard instruments for a period of 38 years. Little attempt is here made to explain the causes of the results obtained. During the period under consideration the exposure of the thermometer was changed twice, the present exposure being that inside the standard instrument shelter of the United States Weather Bureau located on the roof of the Boston Post-Office Building. Its height is 115 feet above the street level and 125 feet above the level of the sea. In regard to the changes in the position of the instruments, it should be stated that neither of the two changes was great enough to affect the results in any marked degree, as the three locations are less than 200 feet apart horizontally and not more than 25 feet vertically. Although there was undoubtedly some slight effect caused by these changes in exposure, it was so slight that no correction was applied by the Weather Bureau, and none has been applied in the present study. It should also be stated that all of the temperature readings are given in degrees Fahrenheit.

[1] A study of the temperatures of Boston, based upon the observations made by the United States Signal Service and the United States Weather Bureau during the period January 1, 1871–January 1, 1909, consisting of a brief summary of a thesis prepared under the direction of Prof. R. DeC. Ward in an advanced course in climatology, Geology 20e, at Harvard University, between February and June, 1909.

Monthly and annual mean temperatures.[2]

Year.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1871....	26	29	42	47	58	66	71	72	**59**	54	37	28	48.9
1872....	27	28	**26**	47	59	69	**76**	73	64	52	41	23	48.8
1873....	25	26	34	45	57	67	73	70	63	54	**33**	32	48.2
1874....	30	27	34	**39**	55	66	73	68	64	53	42	31	48.6
1875....	**20**	22	31	43	58	67	72	71	61	50	35	30	**46.6**
1876....	31	27	33	44	55	69	74	70	60	48	41	**22**	47.9
1877....	25	**34**	35	44	55	67	71	72	65	52	44	36	50.1
1878....	28	31	40	48	56	65	74	70	64	56	41	30	50.2
1879....	24	25	34	42	60	65	71	69	62	**58**	39	32	48.4
1880....	35	32	33	46	**64**	69	73	71	65	52	38	27	50.3
1881....	22	28	37	44	57	62	70	71	**68**	54	44	39	49.6
1882....	26	30	36	43	**51**	67	73	72	64	55	39	30	48.8
1883....	24	29	31	45	56	**70**	72	68	60	**48**	43	29	47.9
1884....	24	31	34	44	55	67	69	70	67	53	41	34	49.0
1885....	27	**21**	28	47	53	67	72	68	60	52	44	33	47.6
1886....	26	27	33	49	57	63	71	68	63	52	43	28	48.4
1887....	25	29	32	44	60	65	75	68	60	52	42	32	48.5
1888....	**20**	28	32	43	53	67	69	70	60	48	44	35	47.3
1889....	**36**	26	38	43	60	69	69	67	63	48	45	38	50.7
1890....	32	33	35	46	57	64	71	69	63	51	42	26	49.1
1891....	31	32	34	48	56	65	69	70	67	52	41	**40**	50.4
1892....	28	28	33	48	56	**70**	73	70	62	53	41	30	49.4
1893....	21	27	34	44	56	65	71	70	60	55	42	30	47.9
1894....	30	27	42	47	58	69	74	68	65	54	38	32	50.3
1895....	29	25	35	46	60	67	69	71	66	50	45	36	49.8
1896....	25	29	32	47	60	66	72	71	62	50	**46**	30	49.2
1897....	28	31	37	**49**	58	62	72	70	63	54	41	34	49.9
1898....	29	33	43	44	56	66	72	**73**	66	54	42	32	50.8
1899....	29	27	34	48	58	**70**	73	69	62	54	42	36	50.2
1900....	30	29	34	**49**	55	69	74	71	65	57	45	33	50.8
1901....	28	24	36	44	54	68	73	71	65	54	37	32	49.0
1902....	27	29	43	48	58	64	**68**	68	63	54	**46**	28	49.6
1903....	27	31	**44**	48	58	**60**	71	**65**	64	54	40	29	49.5
1904....	22	23	35	45	61	64	71	69	62	51	38	26	47.1
1905....	25	23	37	47	58	65	73	69	62	54	45	35	49.1
1906....	**36**	30	32	47	58	66	70	72	65	52	42	29	50.0
1907....	27	22	38	43	52	65	72	70	64	50	43	37	48.7
1908....	31	27	39	47	59	**70**	74	69	66	55	44	33	**51.2**
Means..	27.3	27.9	35.3	45.7	57.0	66.4	71.8	69.8	63.3	52.7	41.4	31.5	49.2

NOTE.—Bold face figures indicate highest and lowest monthly means.

The mean monthly temperatures consist of the averages of the mean temperatures of all the days which constitute each of the several months, while the mean annual temperatures are the means of the 12 mean monthly temperatures.

In general it may be said that the departures of the mean temperatures of individual months from the established normals decrease during the summer and increase during the winter. In other words, the summer months depart from the normals for these months by small amounts (in their mean temperatures), while winter months frequently are considerably warmer or colder than the established averages for those months. In regard to periodicity, while it is true that there are many instances of 5 or more months in successive years either above or below the normal in their mean temperatures, these do not occur during the same periods for successive months, neither do the periods alternate on one side of the normal and then on the other for any given month during successive years.

Of the 4 seasons, spring is nearest, in its mean temperature, to that for the year, being only 3.2° less than 49.2°, the average established for the year. On the other hand, the mean temperature for winter is 20.3° lower than the normal for the year. During the period of 38 years considered, 3 winters have been more than 4° warmer than the average, while 4 winters have been colder than the average by the same amount. There is a series of 6 consecutive years, 1883–1888, inclusive, with abnormally cold winters, and another series of 5 consecutive years, 1896–1900, inclusive, in which the winters were abnormally warm. The fact that these periods are separated by alternately warm and cold winters does not allow the conclusion to be drawn that a series of cold winters is followed by a series of warm winters, nor that there is a periodic or a recurring condition in the thermal characteristics of the winter season. (In this summary the winter of any year refers to the winter of which the first 2 months of that year form a part).

The range of the departures for spring is considerably less than that of winter, there being but one departure in spring of 4° or more. There is a series of 6 years, 1872–1877, inclusive, in which the mean temperature of spring is uniformly below the normal, and another series of the same number of years, 1894–1899, inclusive, in which the spring seasons are warmer than the normal. These 2 series are separated, however, by 16 years of alternately warm and cold springs.

Of all the seasons of the year, summer is least likely to deviate from the normal in its temperature by a large amount, as is shown by the fact that there is only 1 positive departure, in the 38 years, of over 2° and but 2 negative departures of the same amount. Moreover, there is no suggestion of alternate series of warm and cold summers, as there is not a single period of 5 or more consecutive years in which the mean summer temperatures are uniformly above or below the normal.

In its departures from the mean, the temperatures of autumn resemble those of summer in the decreased range of its departures. Moreover, it more nearly resembles summer in this respect than does spring, there being no departures of 4° or more from the normal, and only 1 positive and 1 negative departure of at least 3°. There is 1 period of 6 consecutive years, 1895–1900, inclusive, in which the autumn means are all above the normal.

The fact that only 1 year since 1871, has had a mean temperature which differed from the normal by more than 2° makes it absurd to speak of any one of these years being decidedly warm or cold. The year with the greatest departure was 1875, when the mean temperature was 46.6°, or 2.6° below the normal. The warmest year here considered was 1908, with a mean temperature of 51.2°, or exactly 2° above the normal. There are 2 series of years in which the mean temperatures are uniformly below normal, the first of 6 years, 1871–1876, inclusive, and the other of 7 years, 1882–1888, inclusive. The fact that these 2 periods are separated by 5 alternately warm and cold years offsets the idea of periodicity. The temperature conditions of the 38 years may be described, in relative terms, as follows: 6 cold years, 5 alternately warm and cold years, 7 cold years, 8 alternately warm and cold years, 4 warm years, and 8 alternately warm and cold years.

THE MAXIMUM AND MINIMUM TEMPERATURES.

The mean monthly extremes are as regular in their changes as are the mean monthly temperatures. Moreover, the mean monthly range is strikingly regular in its increase, during the latter half of the year, to a maximum in midwinter, and in its decrease, during the first half of the year, to a minimum in August—the usual characteristic for intermediate latitudes.

A record of the maximum and minimum temperatures for each one of a long number of years is often regarded as unreliable by an investigator because of a characteristic of human nature by which unusual experiences are greatly magnified when viewed in retrospect, and for that reason extremes of temperature are thought of as being greater than was actually the case. Moreover, the fact that if the investigator has changed his place of residence from a warmer to a colder house, or vice versa, or has moved from the country to the city, or vice versa, it may have greatly affected his experiences during extremes. Furthermore, it should be said that the extremes here given are those recorded by tested instruments located in a standard shelter on the roof of a building, as stated above, and hence need not agree with the true temperatures at the street level below, with incorrect temperatures shown by inaccurate instruments variously located or improperly exposed.

It was found that the extreme maximum temperature for each year has not been below 91°, the mean annual extreme maximum for the period being 95.4° It is worthy of note that the highest temperature experienced in 38 years, namely, 102°, occurred in September, an autumn month, and 2 months after the warmest day of the year in the average. In the case of the extreme minimum temperatures, the disagreement with most people's impressions of past experiences is more marked, partly because of the real difference in the temperature conditions in

[2] Computed at the Boston Station of the United States Weather Bureau.

the roof shelter and on the street level, but principally because of the inaccuracy of cheap thermometers in recording low temperatures. The lowest temperature of the period occurred in January, although the coldest day in the average comes in February. By a singular coincidence the highest and the lowest temperatures recorded in the whole period are separated in time by less than 5 months, the difference between the maximum of September 7, 1881 (102°), and the minimum of January 24, 1882 (−13°), being 115°.

The range between the extreme temperatures of each year is fairly uniform for the period, it being never less than 90° nor more than 108°, the mean annual range being 99.7°. In the case of the monthly range of extreme temperatures, those of the summer months are small, while those of the winter months are comparatively large.

A selection of the warmest and the coldest months of the period brings out the fact that the winter months depart further from the normal both in their maxima and in their minima than do the summer months. December and March each have a range of 18° between the maximum and minimum mean monthly temperatures, while July and August each have a range of less than half that amount, namely, 8°. Such a condition might be expected from the difference in variability of the 2 halves of the year, as shown above. It is also noteworthy that in only 1 case are 2 consecutive months the warmest in the period, this being true for July and August, 1872, the latter month, however, being no warmer than August, 1898. In the list of coldest months, 1888 appears twice, as does also 1903.

The range between the warmest and coldest mean seasonal temperatures during the period shows a decrease from the maximum of 10.0° in winter to a minimum of 7.0° in autumn, summer having but 0.1° greater range in this respect than spring. It is also worthy of note that no 2 warm seasons occur in any 1 year, while but 2 cold seasons occur in 1 year, the latter case being the winter and autumn of 1875.

The warmest year of the 38, 1908, does not contain any 1 season which is the warmest for the period. On the other hand, 1875, the coldest year, had 2 seasons which were respectively the coldest in the period. The year 1908 was 2° warmer than the average, while 1875 was 2.6° colder than the normal. The relative sameness in the temperatures of recurring years is shown by the fact that the range between the mean of the warmest and the coldest years, respectively, of the period was only 4.6°.

A determination of the percentage of the normal seasons, and seasons above or below normal, in their mean temperatures, brings out the fact that autumn and winter are less likely to be normal in their means than are spring and summer. The fact that a fairly equal proportion of the seasons of the past 38 years has been above and below normal justifies the statement already made that no progressive change, either above or below the normal, is to be noted during the period.

A study of the relation of warm and cold winters and summers to the mean temperatures of the seasons following seems to show that a warm or cold winter or summer is far more likely to be followed by average seasons, for the next year at least, than by similarly warm or cold seasons. In other words, it is more likely that a cold winter will be followed by an average spring than by a cold spring. In only 3 cases out of a possible 16 has a warm or a cold season been followed by other than average seasons. In a similar manner, in the case of the 8 cold years that have occurred, 5 of the years following have, in each case, been average in temperature, while for the 8 warm years, 6 have been followed by average years.

THE DAILY TEMPERATURES.

In order to obtain the mean temperature for each day of the year, the average of the maximum and minimum temperatures of each day of the last 37 years, 1872–1908, inclusive, was obtained at the Boston station. The average of the 37 maxima gave the mean maximum, and the same for the minima gave the mean minimum for each day of the year. The average of the mean maximum and mean minimum temperatures was taken as the mean daily temperature, similar to the method employed by the Weather Bureau. (According to Professor Hann, the eminent European authority, this average is somewhat higher than the true mean, "the difference being about 1.3° F. in the majority of climates throughout the year.") It is to be noted that February 2 is, in the average, the coldest day of the year, with a temperature of 23.4°, while July 8, with a temperature of 73.0°, is the warmest. It is a peculiar fact that the coldest day of the year does not occur in the coldest month of the year, namely, January.

The irregularity from day to day, as well as the general rise and fall with the season, of the mean daily temperature is apparent when curves based upon these means are drawn. The period of 38 years is not sufficiently long to overcome these irregular changes, and a considerably longer time will be required to make the curve a smooth one.

It is to be noted that there are several instances of periods of 3 to 6 consecutive days which are relatively warm or cold as compared with the immediately preceding or following days, due allowance being made for the seasonal rise or fall of temperature. This is a condition which is not peculiar to Boston, but is found wherever the mean daily temperatures have been studied. In Europe the matter has received careful attention, and many such periods have been found to occur simultaneously over wide areas. In the United States the mean daily temperatures for Baltimore alone have been studied in this connection.

From a long series of observations made in Europe, Dr. R. Assmann has shown that May 10–13 is abnormally cold over a region extending from Scandanavia through central Europe. W. J. Van Bebber, from a series of weather maps, has pointed out a parallel series of progressive pressure departures over the same area, giving clear skies, northerly winds, and hence low temperatures. Such days as these have received special names, these particular ones being called the "Three Ice Saints" or the "Three Ice Men." In Baltimore and in Boston no abnormally cold period occurs about that time. In fact, May 9–12, inclusive, is an unusually warm period at both places. Both cities also agree in having warm periods at other times of the year, such as March 7–12, April 12–13, December 21–23, and most markedly, January 21–23, all inclusive. However, Baltimore experiences a cold period of 2 or 3 days about June 20, and another about July 20, which Boston does not have. Moreover, Boston has a warm period from February 10–16, inclusive, which the temperature curves of Baltimore do not even suggest. All of these irregularities invite investigation as to their causation.

No evidence of periodicity is seen in the mean daily temperatures of Boston. The regular march of the temperature upward in spring and downward in autumn is often overcome by irregular changes when 2 or 3 days only are considered. However, when a period of 10 or more days is taken, the general tendency is easily apparent. It is a noteworthy fact that the irregular changes in the maximum and minimum temperatures are quite parallel, an abrupt rise in the one generally being accompanied by a similar abrupt rise in the other, the same being true for decreases in temperature. As the mean is simply the average of these 2, it naturally follows that curves based upon the 3 kinds of mean temperatures will therefore be somewhat parallel, though very irregular throughout.

THE HOURLY TEMPERATURES.

It has been the custom of the Weather Bureau (until 1905) to record the temperature of each hour of the day, as deduced from the corrected thermograph record. From these data the mean hourly temperature for every month of the years 1890–1904, inclusive, has been obtained. The period of 15 years is probably sufficiently long to make the averages reliable, a total of 131,472 observations serving as a basis for the final table of means.

The changes from hour to hour and from month to month are regular and even, no striking exceptions having been noted. As might have been expected, the coldest hour of the 24 varies somewhat, owing to the change, from month to month, in the time of sunrise. It appears to be the hour 6–7 a. m. in the colder part of the winter, and the hour 4–5 a. m. in the warmer part of the summer. The change in the hour of maximum temperature is not so marked, the exact time being about 3 o'clock in the afternoon in winter, while in summer it is nearer 2 o'clock.

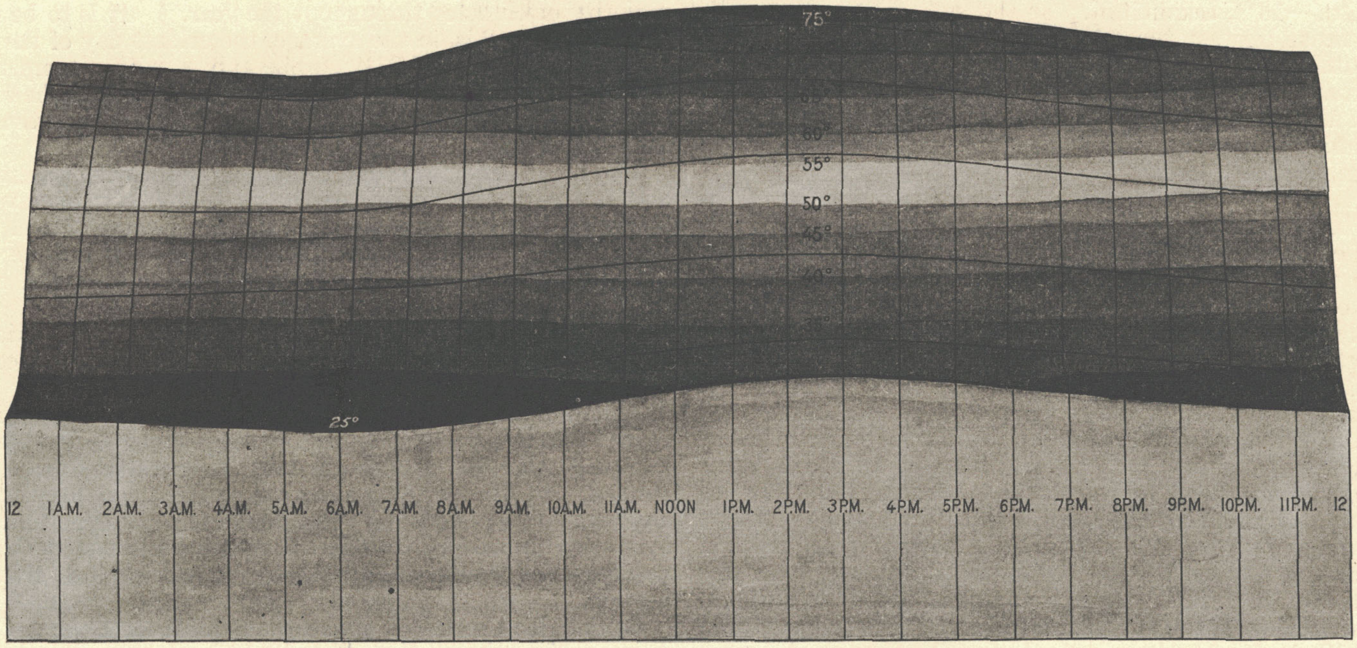

FIG. 1.—Model of "chronoisotherms" for Boston, Mass. (Side view.)

THE MODEL OF THE CHRONOISOTHERMS OF BOSTON.

As an outgrowth of the research, of which the accompanying paper is a brief summary, a model of the "chronoisotherms" of Boston was also made (see figs. 1 and 2). The model is constructed of plaster of Paris, and is probably the first of its kind. It has been placed in permanent position in the Geological Museum of Harvard University. The model is 2 feet long and 1 foot wide, and its 3 dimensions show months, hours, and temperatures. Along one side of the rectangular base vertical lines are drawn, at equal intervals, to show the 24 hours (see fig. 1), and along the other side 12 vertical lines represent the months (see fig. 2). The heights of the upper surface of the model, measured from the base, represent the mean hourly temperatures. This upper surface is subdivided into 12 areas, representing different degrees of heat and cold, and each area is colored, different shades of red being used for the higher temperatures, and different shades of blue for the lower. By means of this model it is possible to ascertain, easily and with great accuracy, the mean temperature of any hour of any month of the year. The data used in the construction are the averages of the hourly temperatures recorded at the Boston office of the United States Weather Bureau during the period of 15 years, 1890–1904, inclusive, consisting of a total of 131,472 observations. The modelling of climatological data in clay or plaster of Paris is a wholly new idea, and such models are likely to be of value in the climatological instruction of the future.

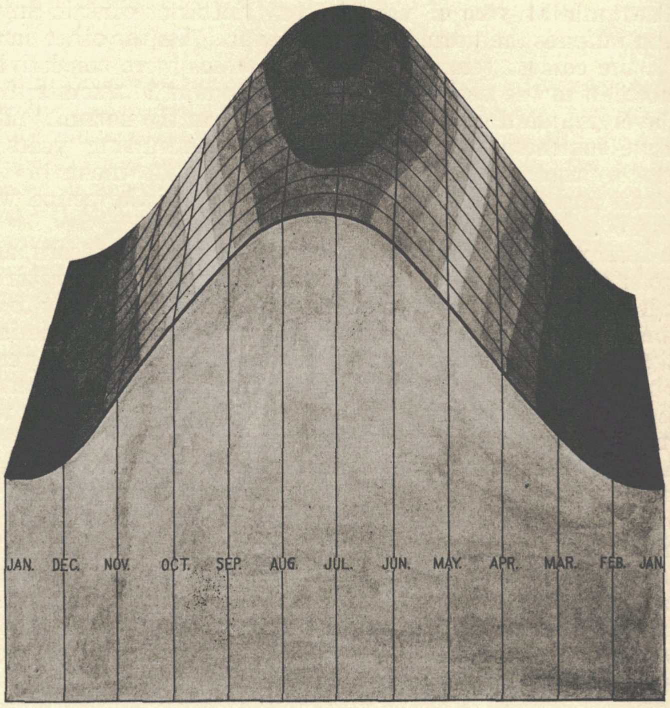

FIG. 2.—Model of "chronoisotherms" for Boston, Mass. (End view.)